Title: Microhardness of dual-polymerizing resin cements and foundation composite resins for luting fiber-reinforced posts

Abstract

Statement of problem. The optimal luting material for fiber-reinforced posts, to ensure the longevity of foundation restorations, remains undetermined.

Purpose. The purpose of this study was to evaluate the suitability of 3 dual-polymerizing resin cements (DRCs) and 2 dual-polymerizing foundation composite resins (DFCRs) for luting fiber-reinforced posts by assessing their Knoop hardness number (KHN).

Material and methods. Five specimens of DRCs (SA Cement Automix [SAC], G-Cem LincAce [GLA], and Panavia F2.0 [PF2]) and 5 specimens of DFCRs (Clearfil DC Core Plus [DCP] and Unifil Core EM [UCE]) were polymerized from the top by irradiation for 40 seconds. KHNs were measured at depths of 0.5, 2.0, 4.0, 6.0, 8.0, and 10.0 mm at 0.5 hour and 7 days after irradiation. Data were statistically analyzed by repeated measures analysis of variance (ANOVA), 1-way ANOVA, and the Tukey compromise post hoc test (α=.05).

Results. At both times after irradiation, the 5 resins materials showed the highest KHNs at the 0.5-mm depth. At 7 days after irradiation, the KHNs of the resin materials did not differ significantly between the 8.0-mm and 10.0-mm depths (P>.05). For all materials, the KHNs at 7 days after irradiation were significantly higher than those at 0.5 hour after irradiation at all depths (P<.05). At 7 days after irradiation, the KHNs of the 5 resin materials were found to decrease in the following order: DCP, UCE, PF2, SAC, and GLA (P<.05).

Conclusions. The KHN depends on the depth of the cavity, the length of time after irradiation,

and the material brand. Although the KHNs of the 2 DFCRs were higher than those of the 3 DRCs, notable differences were seen among the 5 materials at all depths and at both times after irradiation.

Clinical Implications

Within the limitations of this in vitro study, dual-polymerizing foundation composite resins may be preferable to dual-polymerizing resin cements for luting fiber-reinforced posts into cavities because of their superior KHNs at all cavity depths.

INTRODUCTION

To prevent tooth fracture, an endodontically treated tooth should be protected by a complete coverage restoration.[1,2] If the morphology of the remaining tooth does not promote the stable retention of a foundation material because of caries, fracture trauma, previous restorative procedures, or an endodontic access, a post must be placed in the canal to retain the core.[3,4] For this purpose, the cast post and core, prefabricated post and core, or coronal-radicular foundation may be used, which may be prepared at the chairside or in a dental laboratory. The use of translucent fiber-reinforced composite resin posts in combination with resin luting cements or foundation composite resins has been reported to be effective for the restoration of endodontically treated teeth because they exhibit superior fracture resistance in these weakened teeth.[5,6] Fiber-reinforced composite resin posts exhibit more similar moduli of elasticity to dentin than do metal or ceramic posts, thus reducing the stress within the root

canal and preventing the risk of radicular fracture.[7] The fracture resistance and survival probability of post and core restorations depend on several factors, such as the amount and condition of residual tooth structure, preparation of the tooth for restorative procedures, and characteristics of the fixed restoration, such as post material, core material, and luting cement.[8-14]

Dual-polymerizing composite resins are widely used in modern adhesive restorative dentistry as both foundation resins and luting cements.[3] Autopolymerizing or light-polymerizing composite resins are also appropriate for these applications but have a few limitations. Dual-polymerizing foundation composite resins have been developed to allow the clinician to build extended foundation restorations efficiently, and in bulk, since the chemical mode of the polymerization process can initiate resin polymerization at greater depths.[15] Recently, dual-polymerizing foundation composite resins have also been used to lute prefabricated posts into flared root canals,[16] where a thick composite resin layer would normally be present between the fiber-reinforced post and root walls.[17] However, an excessively thick cement layer in that region may not confer the requisite mechanical properties to withstand occlusal loading.[18] The maximum tensile or shear stress, which is primarily located at the post/cement/dentin interface, decreases with the increasing modulus of elasticity[19]; the modulus of elasticity of the foundation composite resins is higher than that of the resin luting cement.[20,21]

The constitution of the core and post, which forms a mechanically homogeneous unit with root dentin, is difficult to determine and could be compromised if the dual-polymerizing resin cement used does not reach an adequate monomer conversion.[22-24] When dual-polymerizing

resin cements are used to lute the fiber-reinforced post in the prepared root canal, polymerization occurs in a coronal direction. Therefore, their properties may be different at different depths of the post cavity,[25,26] because of the reduction in light irradiation with increasing depth of cavity. Microhardness, as an indirect measure of monomer conversion,[27,28] can be used to assess the physical properties of the material at different depths.[29] However, microhardness values cannot be linearly correlated if compared across different materials because, in addition to the degree of conversion, other factors such as filler type, size, or loading may affect the hardness of the composite resin.[30-32] Because it is difficult to evaluate the strength of the composite resins or cements at different cavity depths, in the present study, the Knoop hardness number (KHN) was used to indicate the degree of monomer conversion of dual-polymerizing materials at different cavity depths.

The purpose of the present study was to assess the suitability of 3 dual-polymerizing resin cements and 2 dual-polymerizing foundation composite resins for luting fiber-reinforced posts into cavities by evaluating and comparing their microhardness at different cavity depths. The null hypothesis was that the type of dual-polymerizing resin cement or foundation composite resin to be used as a luting material for fiber-reinforced posts, the depth of cavity, and the length of time after irradiation does not affect the microhardness of the material.

MATERIAL AND METHODS

Twenty-five semicylindrical cavities with a half diameter of 1.5 mm and a depth of 11 mm (n=5) were prepared in 5 × 10 × 16 mm transparent acrylic resin blocks (Fig. 1). Two

acrylic resin blocks, with or without a semicylindrical cavity, were placed in a silicone impression material mold (15 × 15 × 20 mm, Exafine Putty Type; GC Corp, Tokyo, Japan) which hollowed out 10 × 10 × 16 mm. The fiber-reinforced posts were cut to a length of 11 mm. The resin materials and the fiber-reinforced posts were obtained from the same manufacturer. All resin materials were applied according to the manufacturer's instructions. After the cavities were filled with one of the 3 dual-polymerizing resin cements (SA Cement Automix [SAC], GCem LincAce [GLA], and Panavia F2.0 [PF2]) or one of the 2 dual-polymerizing foundation composite resins (Clearfil DC Core Plus [DCP] and Unifil Core EM [UCE]) (Table I), each fiber-reinforced post was carefully placed into the center of the cavity while being rotated to touch the bottom of the cavity and the flat surface of the acrylic resin block without a semicylindrical cavity. The upper cavity surface in the resin material was covered with a plastic strip and pressed with a thin cover glass to remove any excess resin. Light-irradiation was provided by placing the tip of the light-emitting diode (LED) light unit (power density: 1000 mW/cm^2; Pencure; J. Morita MFG Corp, Kyoto, Japan) on the plastic strip. The 5 resin materials were polymerized for 40 seconds. After irradiation of all the specimens, the acrylic resin blocks were removed from the silicone impression material mold and separated.

Hardness was measured at the following depths from the light-irradiated surface of the cavity: 0.5, 2.0, 4.0, 6.0, 8.0, and 10.0 mm. For each specimen, the Knoop hardness number (KHN) was measured 5 times at each depth with a microhardness tester (FM-700; Future-Tech Corp, Kawasaki, Japan) at 0.5 hour and 7 days after irradiation. A Knoop diamond indenter was applied under a load of 0.098 N for resin cements or 0.245 N for

foundation composite resins for a dwell time of 15 seconds; the load was then removed, and the long diagonal of the indentation was measured under ×400 magnification. KHN, which is inversely proportional to the square of the long diagonal, was thus calculated. All specimens were stored under dry and dark conditions in a box, which was placed in a biochemical incubator at 37°C to avoid exposure to light and were accessed only to obtain measurements.

The KHN data were statistically analyzed by the repeated measures analysis of variance (ANOVA) test. The following independent variables were analyzed: depth of cavity and time after irradiation for within-subject analysis and type of resin material for between-subject analysis. A 1-way ANOVA with the post hoc Tukey compromise test was used to establish specific differences in KHNs between the groups (α=.05).

RESULTS

Tables II and III summarize the mean KHN and standard deviation of the 5 resin materials at 6 cavity depths after 0.5 hour and 7 days after irradiation. The results of the repeated measures ANOVA revealed that the depth of the cavity and the time after irradiation were significant among the 5 dual-polymerizing resin materials (Table IV, P<.001).

At both times after irradiation, the 5 dual-polymerizing resin materials showed the highest KHNs at the depth of 0.5 mm; the KHN gradually decreased with increasing depth. At 0.5 hour after irradiation, the KHNs of the 3 resin cements did not differ significantly between the depths of 8.0 and 10.0 mm (P<.05). At 7 days after irradiation, the KHNs of all 5 resin materials did not differ significantly between the depths of 8.0 and 10.0 mm (P<.05).

For all the resin materials, the KHNs at 7 days after irradiation were significantly higher than those at 0.5 hour after irradiation at all depths ($P<.05$). At 7 days after irradiation, the KHNs of the 5 resin materials were found to decrease in the following order: DCP, UCE, PF2, SAC, and GLA. Furthermore, the difference in KHNs among the 5 resin materials was statistically significant at all depths and at both times after irradiation ($P<.05$).

DISCUSSION

According to the results of this study, the KHNs of dual-polymerizing resin cements or foundation composite resins depend on the depth of cavity, length of time after irradiation, and brand of resin material. Therefore, the null hypothesis was rejected.

Knoop hardness has been shown to indicate the degree of conversion/polymerization well because of its good correlation with infrared spectroscopy.[27,28] However, predicting an absolute value of degree of conversion by means of an absolute hardness value is not achievable, since other factors such as type and size of filler, filler load, monomer composition, quantity of initiators, and the ratio of chemical-polymerizing and light-polymerizing components strongly influence the final quantity of reacted monomers.[30-32] Microhardness data from the same resin cement should only be compared according to the depth of the root canal or time elapsed since luting.[24] KHNs could be used to reflect the degree of conversion at different depths of a composite resin.[29] Therefore, in the present study, KHNs were measured to reflect monomer conversion at different cavity depths and length of time after irradiation in the dual-polymerizing resin materials.

At both times after irradiation, the 5 dual-polymerizing resin materials showed the highest KHNs at the depth of 0.5 mm; the KHN gradually decreased with increasing depth. This phenomenon could be attributed simply to the direction of photo-initiation. Light irradiation was focused on the top surface of the cavity. Therefore, polymerization of the composite resins by means of photo-activated free radicals may occur immediately at the shallow depths of the cavity. The present finding that the KHN of light-polymerizing and dual-polymerizing composite resins is affected by the depths of the cavity has been previously reported.[25,26]

In this study, at 0.5 hour after irradiation, the KHNs of 3 resin cements did not differ significantly between the depths of 8.0 and 10.0 mm. However, at 7 days after irradiation, the KHNs of 5 dual-polymerizing resin materials did not differ significantly. The chemical-polymerizing mechanism of dual-polymerizing composite resins is usually based on a redox reaction of benzoyl peroxide with aromatic tertiary amines, which generates free radicals that break the aliphatic carbon double bonds to initiate the polymerization process. In spite of causing a rapid increase in the viscosity of the polymer matrix, immediate photo-activation after light irradiation is thought not to hinder the migration of the activated free radicals responsible for further chemically induced polymerization. Although the photo-activated free radicals at the shallow depths of cavity could induce the chain propagation of the resin polymer in the downward direction, the exact polymerization mechanism of dual-polymerizing resin cements and foundation composite resins in cavities of greater depth remains unknown. It is difficult to distinguish clearly between the depths of cavity at which polymerization of the composite resin occurs through photo-initiation and those at which polymerization occurs by means of chemical initiation alone.

In the present study, 5 dual-polymerizing resin materials at all cavity depths affected polymerization 7 days after irradiation, showing statistically higher KHNs than those at 0.5 hour after irradiation. These results are consistent with those of a previous study;[24] however, they differ from those of another study,[23] which did not report changes in microhardness values 24 hours after irradiation. However, the polymerization reaction of the dual-polymerizing materials might be specific,[22] and the resin cements tested in these studies were not the same as those in the present study. In fact, no dual-polymerizing self-adhesive resin cement was evaluated in the former study, and the process of luting the fiber-reinforced post into the cavity was not simulated.

Dual-polymerizing composite resins have also been used as luting materials for prefabricated posts or prefabricated post and core materials into the cavity. In general, superior physical properties are important for a successful restoration. In this study, the KHNs of 2 foundation composite resins were found to be statistically superior to those of 3 resin cements at all cavity depths. Various factors can influence the microhardness of a composite resin, such as filler load, type, or size, or resin matrix type.[33,34] In this study, the filler loads used for the 3 resin cements were as follows: SAC 66%, GLA 63%, and PF2 78% mass. The filler loads used for the 2 foundation composite resins were 74% mass for DCP and 72% mass for UCE. The results of this study show that the KHNs correspond to the amount of filler content, except in the case of PF2, which is in agreement with the results of previous studies.[26,35] The initiator and/or accelerator contained in the primer for the pretreatment of tooth structure in PF2 promote the monomer conversion of the resin. Since this primer was not applied on the cavity wall in the present study, its effectiveness is unknown. The acidic

monomer in adhesive resin cements, which is not present in foundation composite resins, inhibits the amine co-initiator in the dual-polymerizing materials.[11] This in turn adversely affects the polymerization of dual-polymerizing adhesive resin cements containing an acidic monomer. The differences in composition between the 3 resin cements and the 2 foundation composite resins might also be responsible for the difference in their KHN behaviors.

At 7 days after irradiation, the ratios of the mean KHNs at a depth of 10.0 to 0.5 mm in DCP were 0.925 and in UCE were 0.956, much higher than those in SAC (0.742), GLA (0.702), and PF2 (0.787). Dual-polymerizing materials differ markedly in terms of the relative content of light-activated and self-activated catalysts.[36] The differences in the degree of conversion among materials when subjected to various polymerization protocols may consequently be attributed to the variations in catalyst systems. In the present study, it might be inferred that the 2 foundation composite resins exhibit high levels of chemically polymerizing activators compared with the 3 resin cements, compensating for the attenuation of light energy at greater cavity depths. SAC might also contain more chemically polymerizing components than GLA, since at 0.5 hour after irradiation; the KHNs of GLA were significantly higher than those of SAC at all cavity depths, whereas at 7 days after irradiation, the reverse results were noted. Indeed, the polymerization behavior of dual-polymerizing composite resins is strongly related to the material and can vary as a function of composition.[15]

In patients with significant coronal destruction, lost tooth structure must be replaced with a foundation material to attain complete coverage restoration.[1,2] The cast post and core, prefabricated post and core, and coronal-radicular foundation are the available options for this

purpose. The fracture resistance and survival probability of post and core restorations depend on several factors such as the post material, luting agent, amount and condition of residual tooth structure, core material, preparation of the tooth for restorative procedures, and characteristics of the fixed restoration.[8-14] When the cement layer is too thick, the retention of the fiber-reinforced post is significantly decreased.[18] Resin cement thicknesses greater than 100 μm were observed between the interfaces of dentin and fiber-reinforced post at the 1-mm, 4.5-mm, and 8-mm level of the root.[17] No scientific evidence supports the effectiveness of the physical properties of resin cements, including their bonding, when an appropriate post space is produced.[16] Dual-polymerizing foundation composite resins showed superior KHNs, an important physical property of the material, to dual-polymerizing resin cements even at greater cavity depths. Therefore, when luting prefabricated post and core material or coronal-radicular foundation, it may be preferable to use dual-polymerizing foundation composite resins. However, further studies are required to investigate the property of the bonding of dual-polymerizing foundation composite resins to root dentin or metal or fiber-reinforced prefabricated posts to support their use as a luting material.

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The microhardness of 3 dual-polymerizing resin cements and 2 foundation composite resins varied depending on depth of cavity, length of time after irradiation, and material brand.

2. At both times after irradiation, the 2 dual-polymerizing foundation composite resins showed higher KHNs than the 3 dual-polymerizing resin cements at all cavity depths.

3. Dual-polymerizing foundation composite resins might be more reliable for luting fiber-reinforced posts, compared to dual-polymerizing resin cements.

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Figure Legend

Fig.1 Schematic illustration of preparing specimens for measurement of Knoop hardness.

A, acrylic resin blocks (5 × 10 × 16 mm) with or without semicylindrical cavity (half diameter of 1.5 mm and depth of 11 mm). **B,** 2 acrylic resin blocks joined. **C,** 2 acrylic resin blocks placed in silicone impression material mold (15 × 15 × 20 mm). **D,** dual-polymerizing resin cement or foundation composite resin was used to lute fiber-reinforced post, and then irradiated on upper surface with LED light unit. **E,** 2 acrylic resin blocks separated. **F,** Knoop hardness measurement for surface of resin material filled in semicylindrical cavity.

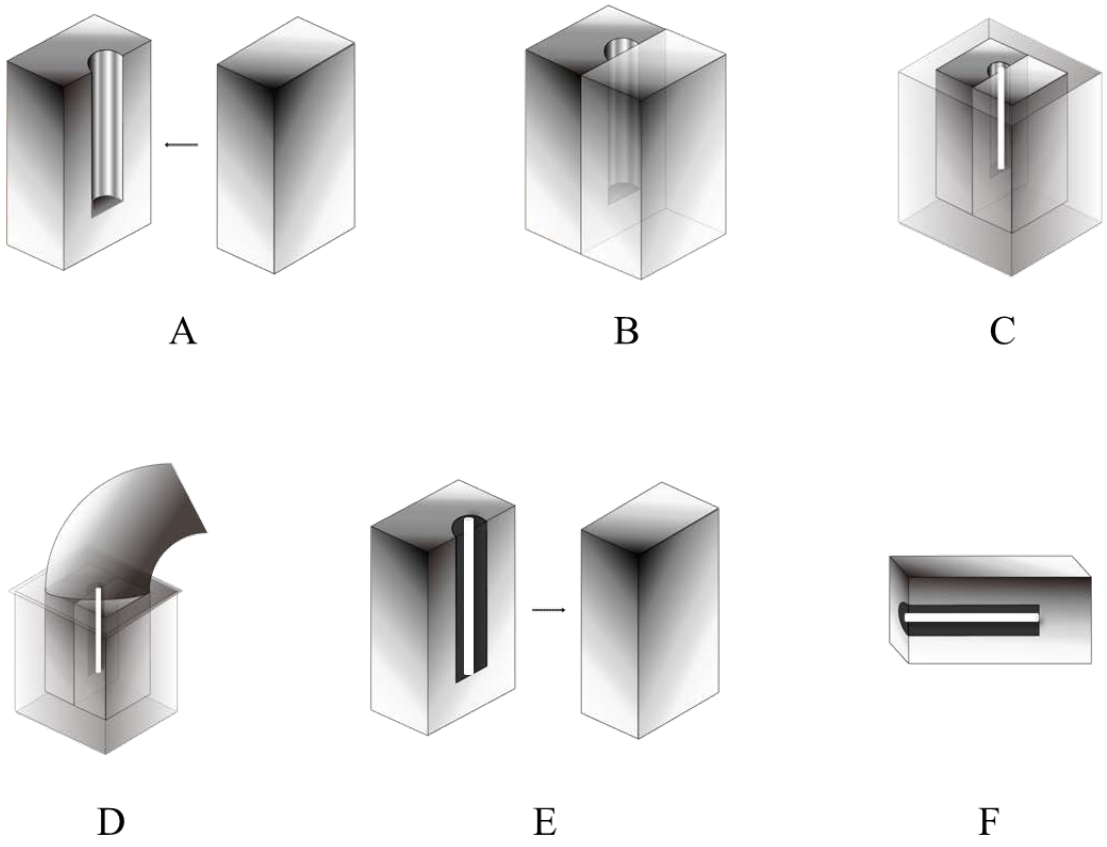

Fig.1

Table I. Materials used in this study

Material	Manufacturer	Composition	Lot No.
Resin Cement			
SA Cement Automix (SAC) A2	Kuraray Noritake Products Corp, Tokyo, Japan	A paste: Bis-GMA, TEGDMA, deimethacryalte, MDP, silanized Ba glass filler, silanized colloidal silica, photo-initiator, chemical-initiator B paste: Bis-GMA, deimethacryalte, silanized Ba glass filler, silanized colloidal silica, silanized NaF, chemical accelerator, pigment	0062AA
G-Cem LinkAce(GLA) A2	GC Corp, Tokyo, Japan	Base: UDMA, dimethacrylate, phosphoric acid ester monomer, F-Al-Si glass, SiO_2, initiator Catalyst: UDMA, dimethacrylate, F-Al-Si glass, accelerator, pigment	1112191 1212144
Panavia F2.0 (PF2) Light	Kuraray Noritake Products Corp	A paste: Bis-GMA, MDP, silanized colloidal silica, silanized SiO_2, chemical-initiator, photo-initiator B paste (light): Bis-GMA, silanized SiO_2, silanized NaF, photo-accelerator, chemical-accelerator, pigment	00563A 0105BA
Foundation Composite Resin			0002AA
Clearfil DC Core Plus (DCP) Dentin	Kuraray Noritake Products Corp	A paste: Bis-GMA, hydrophilic aliphatic dimethacrylate, hydrophobic aliphatic dimethacrylate, hydrophobic aromatic dimethacrylate, silanized Ba glass filler, silanized colloidal silica, colloidal silica, chemical-initiator, photo-initiator, pigments B paste: TEGDMA, hydrophilic aliphatic dimethacrylate, hydrophobic aromatic dimethacrylate, silanized Ba glass filler, silanized colloidal silica, Al_2O_3 filler, photo-accelerator, chemical-accelerator	1107011
Unifil Core EM (UCE) Universal	GC Corp	Base: UDMA, dimethacrylates, F-Al-Si glass, SiO_2, photo-initiator, accelerator Catalyst: UDMA, dimethacrylates, F-Al-Si glass, SiO_2, chemical-initiator, pigment	00009D
Fiber-reinforced post			
Clearfil Fiber Post (No.4, φ1.24)	Kuraray Noritake Products Corp	surface-treated glass fiber, silanized SiO_2, Bis-GMA-TEGDMA copolymer	1208211
Fiber Post (φ1.2)	GC Corp	silanized SiO_2, Bis-GMA-methacrylate copolymer	

Bis-GMA: bis-phenol-A-glycidyldimethacrylate; TEGDMA: triethyleneglycol dimethacrylate; UDMA: urethane dimethacrylate;
MDP: 10-methacryloyloxydecyl dihydrogen phosphate

Table II. Mean KHN values and standard deviations (±) of 5 resin materials at 6 cavity depths 0.5 hour after irradiation

Composite Resin	Depth of Cavity (mm)					
	0.5	2.0	4.0	6.0	8.0	10.0
SA Cement (SAC)	$10.70 \pm 0.28^{a,5}$	$9.92 \pm 0.43^{b,5}$	$8.88 \pm 0.47^{c,5}$	$8.02 \pm 0.33^{d,5}$	$7.31 \pm 0.21^{e,5}$	$7.09 \pm 0.29^{e,5}$
G-Cem LinkAce (GLA)	$12.22 \pm 0.34^{a,4}$	$10.75 \pm 0.26^{b,4}$	$10.28 \pm 0.22^{c,4}$	$9.47 \pm 0.24^{d,4}$	$8.92 \pm 0.29^{e,4}$	$8.43 \pm 0.19^{e,4}$
Panavia F2.0 (PF2)	$18.50 \pm 0.25^{a,3}$	$16.35 \pm 0.28^{b,3}$	$15.34 \pm 0.19^{c,3}$	$14.38 \pm 0.37^{d,3}$	$14.14 \pm 0.62^{d,3}$	$14.37 \pm 0.44^{d,3}$
DC core plus (DCP)	$43.10 \pm 0.96^{a,1}$	$41.58 \pm 0.99^{ab,1}$	$41.05 \pm 1.01^{b,1}$	$40.15 \pm 0.94^{bc,1}$	$38.75 \pm 0.86^{c,1}$	$37.15 \pm 0.84^{d,1}$
Unifil Core EM (UCE)	$35.52 \pm 0.39^{a,2}$	$34.72 \pm 0.60^{ab,2}$	$33.96 \pm 0.60^{b,2}$	$32.65 \pm 0.35^{c,2}$	$31.80 \pm 0.43^{c,2}$	$29.80 \pm 0.73^{d,2}$

same superscript letters indicate no statistically significant differences between depths of cavity at same composite resin (rows); same superscript numbers along with letters indicate no statistically significant differences between type of composite resin at same depth of cavity (columns) ($P>.05$)

Table III. Mean KHN values and standard deviations (±) of 5 resin materials at 6 cavity depths 7 days after irradiation

Composite Resin	Depth of Cavity (mm)					
	0.5	2.0	4.0	6.0	8.0	10.0
SA Cement (SAC)	$16.88 \pm 0.87^{a,4}$	$15.87 \pm 0.96^{ab,4}$	$14.78 \pm 0.87^{bc,4}$	$13.35 \pm 1.07^{cd,4}$	$12.60 \pm 0.91^{d,4}$	$12.52 \pm 0.82^{d,4}$
G-Cem LinkAce (GLA)	$15.28 \pm 0.04^{a,5}$	$13.97 \pm 0.19^{b,5}$	$13.23 \pm 0.18^{c,5}$	$11.99 \pm 0.23^{d,5}$	$11.49 \pm 0.34^{e,5}$	$10.73 \pm 0.54^{e,5}$
Panavia F2.0 (PF2)	$21.50 \pm 0.68^{a,3}$	$19.69 \pm 0.80^{b,3}$	$18.04 \pm 0.36^{c,3}$	$17.65 \pm 0.44^{cd,3}$	$17.11 \pm 0.45^{cd,3}$	$16.91 \pm 0.46^{d,3}$
DC core plus (DCP)	$48.71 \pm 0.71^{a,1}$	$47.59 \pm 0.58^{b,1}$	$46.81 \pm 0.62^{bc,1}$	$46.34 \pm 0.37^{c,1}$	$45.44 \pm 0.29^{d,1}$	$45.06 \pm 0.29^{d,1}$
Unifil Core EM (UCE)	$41.88 \pm 0.18^{a,2}$	$41.08 \pm 0.18^{b,2}$	$40.80 \pm 0.34^{bc,2}$	$40.48 \pm 0.20^{cd,2}$	$40.26 \pm 0.26^{de,2}$	$40.03 \pm 0.24^{e,2}$

same superscript letters indicate no statistically significant differences between depths of cavity at same composite resin (rows); same superscript numbers along with letters indicate no statistically significant differences between type of composite resin at same depth of cavity (columns) ($P>.05$)

Table IV. ANOVA for KHN values of 5 dual-polymerizing resin materials

Composite Resin	Source	df	Sum of Squares	Mean Square	F	P
SA Cement (SAC)	Depth of cavity	5	132.22	26.44	237.48	<.001
	Time after irradiation	1	483.43	483.43	197.43	<.001
	Interaction	5	1.75	.35	3.14	.017
	Error	8	19.59	2.45		
	Total	19	636.99			
G-Cem LinkAce (GLA)	Depth of cavity	5	117.27	23.45	605.91	<.001
	Time after irradiation	1	115.20	115.20	607.71	<.001
	Interaction	5	1.61	.32	8.33	<.001
	Error	8	1.52	.19		
	Total	19	235.60			
Panavia F2.0 (PF2)	Depth of cavity	5	148.5	29.70	283.31	<.001
	Time after irradiation	1	132.20	132.20	157.04	<.001
	Interaction	5	1.22	.25	2.33	.06
	Error	8	6.73	.84		
	Total	19	288.65			
DC core plus (DCP)	Depth of cavity	5	150.24	30.05	237.16	<.001
	Time after irradiation	1	616.87	616.87	216.75	<.001
	Interaction	5	8.25	1.65	13.02	<.001
	Error	8	22.77	2.85		
	Total	19	798.13			
Unifil Core EM (UCE)	Depth of cavity	5	92.91	18.58	365.96	<.001
	Time after irradiation	1	884.97	884.97	1138.95	<.001
	Interaction	5	28.31	5.66	111.50	<.001
	Error	8	6.22	.78		
	Total	19	1012.41			